The Biological Design Process Used in the Development of Federal Government Facilities During Phase I of the Salmonid Enhancement Program

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by

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ABSTRACT

Shepherd, B.G. 1984. The biological design process used in the development of federal government facilities during Phase I of the Salmonid Enhancement Program. Can. Tech. Rep. Fish. Aquat. Sci. 1275: v + 188 p.

This report outlines the processes developed to ensure biological input to the design of federal government facilities during Phase I of the Salmonid Enhancement Program. The report details the components of the biological design process in a step-by-step fashion. The report also provides an overview as to the need for such a process where there is commitment to a significant program of development of enhancement facilities.

Key words: hatcheries, enhancement, bioengineering, design, salmonids, Oncorhynchus, criteria, administration.

RÉSUMÉ

Shepherd, B.G. 1984. The biological design process used in the development of federal government facilities during Phase I of the Salmonid Enhancement Program. Can. Tech. Rep. Fish. Aquat. Sci. 1275: v + 188 p.

Le présent rapport porte sur les processus mis au point afin d'assurer un apport biologique à la conception d'installations du gouvernement fédéral au cours de la première phase du Programme de mise en valeur des salmonidés. Les composantes du processus de conception biologuiqe sont détaillées point par point. Le rapport fournit aussi une vue d'ensemble pour ce qui est du besoin d'un tel processus quand existe l'obligation de réaliser un important programme de développement d'installations pour la mise en valeur.

INTRODUCTION

Pearse (1982) recommended a cautious approach to salmonid enhancement, giving top priority to "careful monitoring and evaluation" of Phase I projects; in the interim, he felt "higher priority should be accorded to well proven techniques, smaller and less risky projects ..." than to major projects.

At the time of publication of this report, SEP in fact has become far more conservative in planning and constructing new major projects. This approach has merit if it allows more effort to be directed towards assessment of existing facilities. However, such a strategy also is likely to result in loss of expertise at the detailed facility planning level if there is a prolonged period of evaluation of existing facilities. Having been involved from the outset in the development of an effective bioengineering interface, I felt a formal overview was necessary in order to guard against future potential loss of development expertise.

This report outlines the development of processes that ensured biological input to the design of federal government facilities during Phase I of the Salmonid Enhancement Program (SEP).

THE SCOPE OF THIS REPORT

It is emphasized that this report reviews just one aspect of the enhancement facility design process, the procedures used by the Enhancement Operations group to provide biological input to the design of those new facilities which the group was to operate. In paticular, this report discusses engineering procedures only where they relate to bioengineering interfaces. The Engineering group invests more time and effort in the development of facilities than all other groups combined, making the engineering design process well worth documentation in a separate report. Also, it should be noted that the Special Projects Group also has constructed facilities within SEP, generally using more conservative criteria (Appendix 1) to allow for training of the operating staffs used in their program.

The New Projects Unit approach is not displayed here as the perfect process (although a striking example of parallel evolution is the criteria development process for an Idaho hatchery, as outlined by Jeppson and Taylor, 1981). In fact, the design process as described in this report has never been followed fully for a particular project. Rather, the outline represents the author's personal perspective of the best possible approach.

This report is meant primarily to give Enhancement Operations staff a better understanding of how the present design approach came to be, what its constraints are, and how it can be improved in the future. Secondarily, it is felt that the report may be of wider interest; other groups may find our experiences worth review

prior to their becoming involved in a major facility development program.

THE SALMONID ENHANCEMENT PROGRAM

For the reader to appreciate the limited scope of this report, some background on SEP is necessary.

Objectives

In the early 1900s, the potential yield of British Columbia's salmonid stocks was twice that of the 1970s. The primary objective of SEP is to return to that higher level of production. A two-year planning process began in 1975, culminating in a phased multiple-objective program proposal (Anonymous, 1978). The program, to be staged in two or more phases, is to restore historic stock levels by the mix of technologies that will best contribute to the federal government's national income, regional development, employment, native Indian well-being, and environmental preservation goals.[a] The first phase of the program was funded for five years (subsequently extended to seven years with no additional funds) beginning in 1977, and was to increase the annual catch of salmon by 23 million kilograms. From the outset, funding beyond 1984 was to be dependent upon the success of Phase I.

General Organization of SEP

The organizational structure required to drive a multiple-technology, multiple-objective program such as SEP is of necessity complex. The reader is referred to Pearse (1982) for a review of the form and function of the senior directive bodies of SEP; Figure 1 provides an overview of the senior framework up to September of 1983. Prior to that date, there were five line groups which reported to the Executive Director or his Associate Director:

Line Group	Description of Responsibilities
Finance	- Administrative and financial support
Program Development	- Program policy and direction studies - Biological and economic analyses of project 'manageability' and 'desirability' - Systems analysis/statistical support
Special Projects	- Implementation and supervision of community-contracted and public involvement projects - Unmanned stream improvement projects - Program information support - Bioengineering reconnaissance and feasibility studies of 'enhanceability' of new projects

a Commonly known as the 'five-account' system.

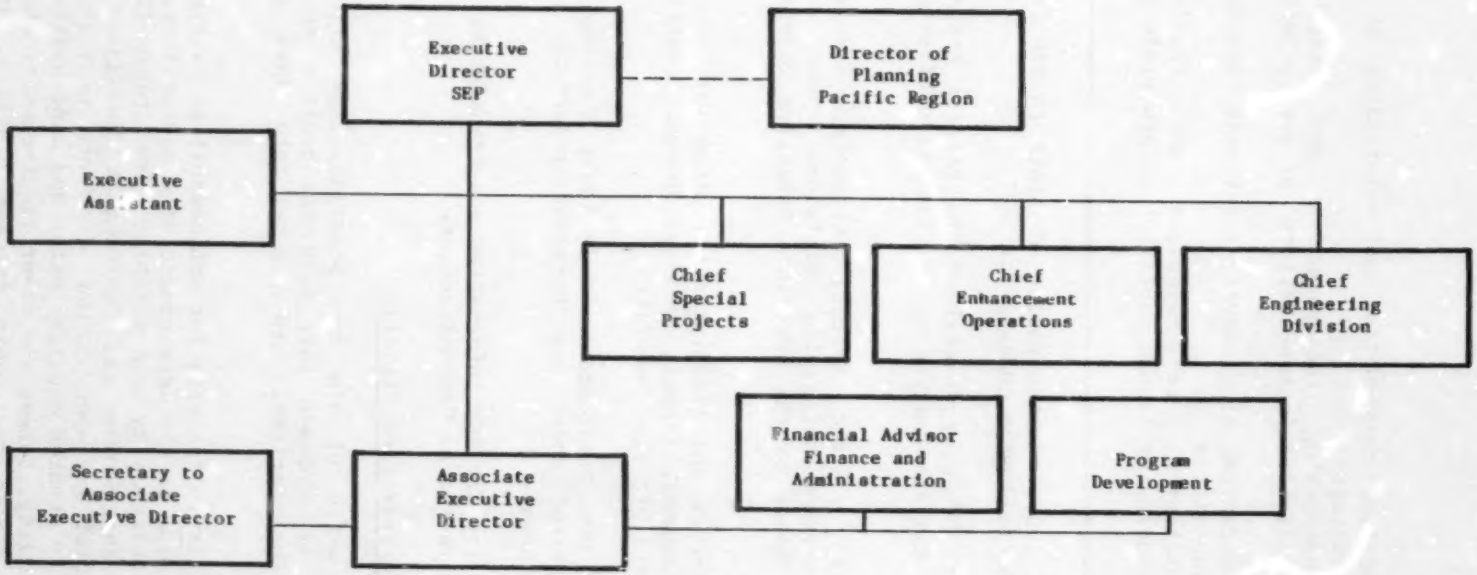

Figure 1. S.E.P. direction and planning: the senior administrative framework prior to September, 1983

Engineering	- Design, construction and maintenance of major projects - Engineering reconnaissance and feasibility studies of 'enhanceability' of new projects
Enhancement Operations	- Operation of federal government enhancement facilities - Biological reconnaissance and feasibility studies of 'enhanceability' of new projects

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In September of 1983, reorganization of staff in the Pacific Region resulted in the following changes for SEP:

(1) An Associate Director General of the Pacific Region was appointed, who also serves as the Executive Director for SEP.

(2) The Chiefs of the Special Projects, Enhancement Operations and Engineering Divisions report on a day-to-day basis to the Associate Executive Director of SEP.

(3) The SEP Finance and Administration group was integrated into the Regional Support Services Branch reporting to the Associate Director General.

(4) The SEP Program Development and Regional Planning groups were integrated under one Director reporting to the Director General.

(5) Responsibility for SEP information was transferred to the Regional Director of Communications.

Enhancement Technical Selection Criteria

Regardless of which of the two possible line groups an enhancement project is proposed for, each new project must meet several criteria. These criteria are grouped into three general areas:

(1) Enhanceability. Analysis for enhanceability is typically the first step in the development of a new project. This can be undertaken by any of three line groups (Special Projects, Engineering and Enhancement Operations), and the potential for duplication of effort is high. Enhanceability studies consider water and land availability and suitability, access and power requirements, abundance of donor stocks and their disease profiles, and the

potential impact on other natural resources (detailed in later sections).

(2) Manageability. These analyses are undertaken by one of three[a] Geographic Working Groups (GWG). Each GWG is composed of senior federal and provincial management biologists, the Federal Fisheries District Supervisor, and a representative from the Habitat Management Branch. The GWG also provides a regional perspective for SEP proposals. A planning biologist from the SEP Program Development Group was assigned to each GWG, to transmit SEP project proposals to the GWG and to provide analytical support as required by the GWG. Manageability evaluations focus on assessing whether the stocks to be enhanced can be managed as discrete units without overexploitation or detrimental impacts on other stocks, and whether the proposed production levels are compatible both with the carrying capacities of the environment and with other departmental programs. Decisions and recommendations from the GWGs are forwarded to the SEP Executive Management Committee, which is comprised of the SEP Executive and Associate Directors, the Chiefs of the line groups, and representatives from the Field Services Branch, the Fisheries Research Branch and the province.

(3) Desirability. Planning biologists and economists evaluate each proposal in terms of the five account framework. The federal Treasury Board's Guide to Benefit-Cost Analysis sets the rules under which net national income benefits and benefit-cost ratios are calculated; key indicators for each of the other four accounts are subjectively scored and weighed to provide a rating for each account (for details see Economics Working Group, MS 1977). Technical desirability is not formally assessed for factors such as contribution to technological development, minimization of technological risk and energy needs for operation of facilities, and avoidance of foreclosure of future options. Rather, these items are considered on an ad-hoc basis for individual projects by the biological and engineering groups involved. If dissension between groups is severe, the matter is referred to the Executive Director for a decision.

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[a] North Coast, South Coast, and Fraser R. - Northern B.C. - Yukon; geographic limits of jurisdiction correspond to those of the Field Services Divisions.

Organization of the Enhancement Operations Group

It is perhaps useful to review briefly the evolution of Enhancement Operations. Prior to 1971, Departmental biological activities were organized by the species of salmon associated with major gear types (Southern Net Species, Northern Net Species, and Chinook/Coho Groups). Because the few culture facilities then in operation were dominated by chum, pink and sockeye, with chinook and coho culture largely experimental, the two Net Species groups administered the existing facilities.

In 1971, as a result of a Management By Objective (MBO) exercise, the Department was split geographically into two branches and six divisions:

Branch	Division
North Coast	Northern B.C. and Yukon
	North Coast
	Central Coast
South Coast	West Coast Vancouver Island
	Georgia Strait
	Fraser River - Johnstone Strait

Enhancement facilities were administered by the geographically appropriate division. This arrangement turned out to be somewhat unwieldy and was simplified in 1976 to the present system of three geographic Divisions (North Coast, South Coast, and Fraser River - Northern B.C. - Yukon).

With the formation of the-then Enhancement Services Branch in 1977, there was an initial shift from a geographic to technological grouping of the enhancement facilities into Hatcheries, Spawning Channels, Incubation Systems, and Small Projects sub-groups. This rapidly proved unworkable, what with combination facilities and other logistical difficulties. By mid-1978, the four sub-groups had coalesced into two, a Hatcheries Group and an Incubation Systems Group. Functionally, however, all staff members except the two Group Managers were assigned to one or two facilities, and they thus largely retained a geographic separation in their working relationships. This caused a number of problems, particularly for new facilities. Biological input to the design process was inconsistent, poorly documented, and fragmented in approach. Project engineers would query the biological staff members that they thought could address the particular design problem. Such advice was often given off-hand, without complete appreciation of the particular situation or with only restricted experience of certain

technologies, and therefore varied considerably. Some engineers took informal polls of the biological staff and then took it upon themselves to resolve the discrepancies and come to the 'right' answer. This caused a lot of confrontation, and attempts to research the bases for design decisions were often frustrated due to the lack of documentation of the information base and the assumptions used. In 1977, the Hatcheries Group Manager suggested that a large regional fish culture program required the following functional systems: (1) Information; (2) Program Assessment; (3) Technical Support; (4) Operation Support; and (5) New Projects (Sinclair, MS 1977). A major increase in bioengineering reconnaissance activity further emphasized the need for a separate group to deal with new projects on the regional level, and this was reflected in the reorganization of Enhancement Operations into its present structure in 1979.

The Enhancement Operations line group now is divided into five units (Fig. 2). Three of these units are responsible for the operation of existing facilities and have geographic boundaries identical to those of the GWGs and Field Services Divisions.[a] There is also a Biological Program Coordination Unit which is responsible for meshing annual production plans, improving the consistency and rapidity of data reporting from facilities, implementing programs common to all facilities (eg, computer systems and fish food quality control), and assessing the performance of facilities and culture techniques. Finally, there is the New Projects Unit, which is described in greater detail in the next section.

The Role of the New Projects Unit

The duties of the New Projects Unit are:

(1) To gather bioreconnaissance data to a level adequate to support facility design.

(2) In cooperation with the biological staff of Enhancement Operations, to develop biological design criteria for use in facility design.

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[a] The North Coast Unit covers all watersheds draining to the Pacific from the B.C.-Alaska border south to Cape Caution; the South Coast Unit has responsibility for the mainland coastal watersheds between Cape Caution and Howe Sound, Vancouver Island, and all Johnstone-Georgia Strait islands; the Fraser River-Northern B.C.-Yukon Unit handles the Fraser watershed, those watersheds in B.C. draining through the Alaskan Panhandle, and the Yukon.

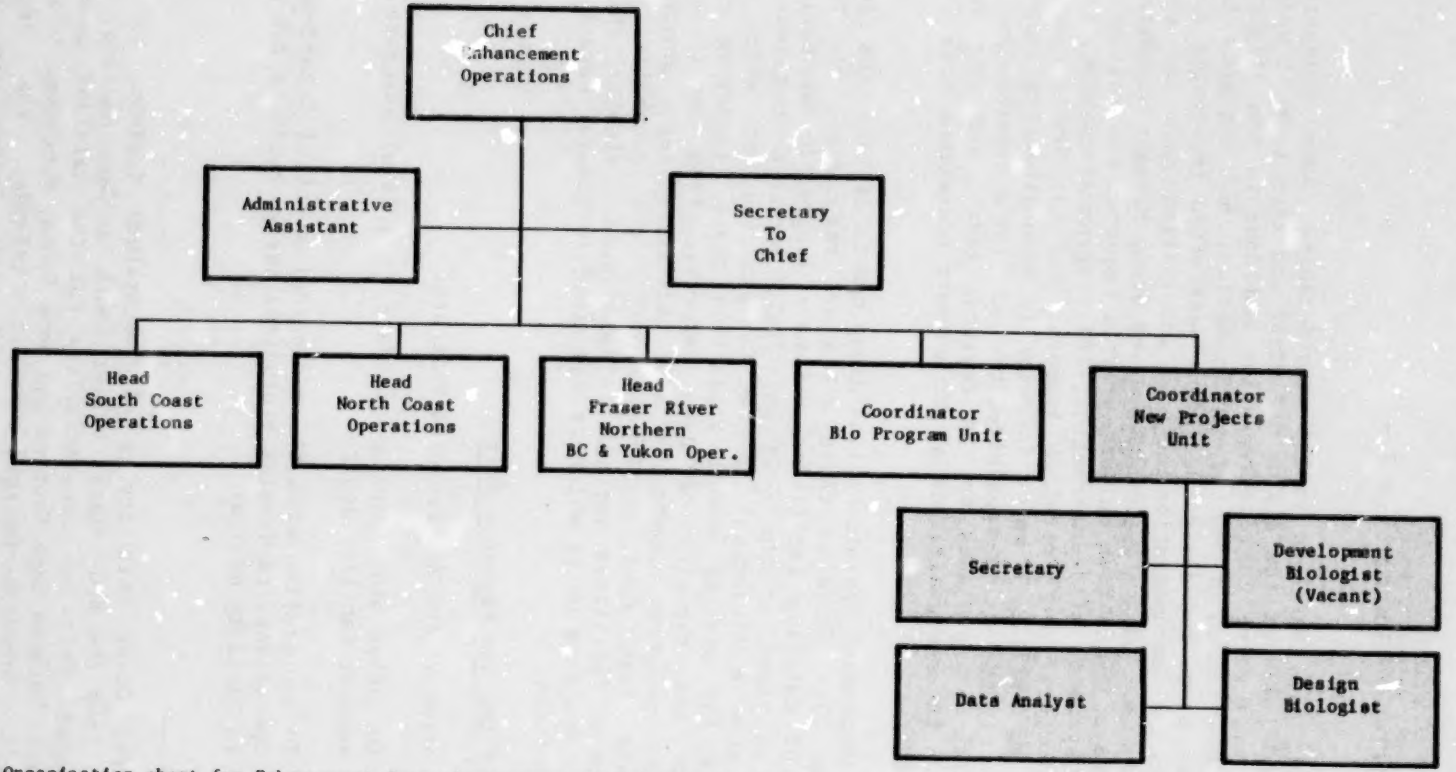

Figure 2. Organization chart for Enhancement Operations group and New Projects Unit

(3) To provide advice and guidance regarding biological criteria to Engineering during facility design, construction, and start-up.

(4) To monitor operational effectiveness of facilities during start-up.

With respect to item (4), manpower limitations have not allowed adequate follow-up, and the New Projects Unit is highly dependent on problem/success feedback from the Operations Units. Although this change has resulted in some items being overlooked in the first few years, it may be a healthy approach in terms of developing group dynamics and inter-unit communication in the long term.

It must be emphasized that the New Projects Unit's role is not to act as the sole source of advice to Engineering, but rather, to focus through coordination the best spectrum of biological expertise on the design problems at hand. The Unit also serves as a communications interface between the rather disparate languages and attitudes of the biological and engineering disciplines. Burrows (1981) felt that such an interface was a necessity.

THE BIOLOGICAL DESIGN PROCESS

AN OVERVIEW OF THE PROCESS

In September of 1976, an inter-agency workshop was held by SEP to review the major salmonid rearing systems that were available. The draft report on that workshop concluded that "...specific engineering design criteria could not be established without the knowledge of site characteristics." (Sinclair, MS 1976). That report called for project planning to "...include a well defined series of events to clearly identify objectives, characterize physical and biological site constraints, systematically assess alternative design options and finally arrive at the most economically efficient and biologically suitable design for the given site." With the exception of a systematic option-assessment procedure, these mechanisms are now part of the basic design cycle.

Table 1 charts the general route that SEP Phase I facility designs have followed (no one project has ever followed this schedule exactly through to completion). The New Projects Unit normally deals with new sites; however, it is also involved where new species or technologies are to be added to existing facilities. Where the expansion of an existing facility is straightforward, the operating personnel deal directly with the Engineering Division. Also, some of the new facilities constructed in Phase I (eg, Chilliwack) were designed before implementation of the present organization. To maintain continuity, those biological staff initially assigned to these projects saw them through to completion with minimal New Projects involvement.

Table 1. Flow chart for design of SEP facilities.

	Item	Groups	Approximate Time Frame
1.	Production objectives	GWG and SEP Senior Executive	
2.	Senior-level reconnaissance to gauge systems' potentials	Bioengineering reconnaissance	4 inspections at key times of year
3.	Detailed feasibility studies	New Projects Unit and Engineering Division	1 - 2 yr
4.	Formal Biological conceptual design	New Projects Unit	2 - 4 wk
5.	Preliminary design drawings	Engineering Division	variable (1 - 6 mo)
6.	Bioengineering concept review	Biological* and Engineering groups	1 - 2 wk
7.	Site layout/flow schematic	Engineering Division	2 - 4 wk
8.	Concept finalization a) blueprint review b) meeting & concept approval	 Biological group Biological and engineering groups	1 - 2 wk
9.	Costing a) Operational b) Capital	 Operations Unit Engineering	1 - 2 wk
10.	Production Forecasts	New Projects Unit	1 wk
11.	Treasury Board submission (includes benefit-cost calculations)	Chief of Engineering Division, Economics Unit section of Program Development group, and New Projects Unit	2 - 4 wk
12.	Treasury Board Approval	Treasury Board	3 wk
13.	Detailed design	Engineering Division (New Projects input as required)	variable (3 wk - 2 mo)
14.	Detailed design review(s) (entire facility, or by components if large) a) blueprint review b) orientation meetings as necessary c) review meetings/memo responses	 Biological group Biological and Engineering Groups Engineering and Biological groups	 1 wk 0.5 day 1 wk
15.	Design completion	Engineering Division	(min. 1 wk) variable
16.	Final design review/approval meeting (double-check inclusion of amendments)	Biological and Engineering groups*	1 wk
17.	Project to tender	Engineering Division	1 - 2 wk

* Biological group normally includes New Projects coordinator and biologist; Operations Unit head, biologist and manager/advisor; Enhancement Operations Chief; and Fish Culture biologist from B.C. Fish and Wildlife where steelhead or cutthroat are being included.

STEPS IN THE PROCESS

Step 1 - Production Objectives

Initially, facility targets were developed in a piecemeal fashion through internal memos among the Engineering Division, various biological groups, and the GWGs. For the first half of Phase I, the GWGs had to catch up. The formulation of management strategies and priorities for each area required considerable effort, and was further complicated by changes in GWG perspectives with staff and data-base changes. The targetting process has now been standardized to the following procedure. With the assistance of Program Development planning biologists, the GWGs divided their regions into a series of management units. Each unit was reviewed as to its stock status and management characteristics and dependencies. On the basis of these reviews, recommendations on the potential and priority for additional production of each species were distributed as a planning document (Schouwenburg et al, MS 1980; for sample excerpt, see Appendix 2). This document is to be updated at regular intervals. The guidance provided in this document is for the most part at the area level. These general objectives are meshed with the physical potential of the site (evaluated by Engineering and New Projects staffs), and facility-specific strategies and targets normally are negotiated as follows. The New Projects Coordinator usually contacts the SEP Planning representative assigned to the GWG, and the Coordinator provides a memo to the GWG outlining the proposed facility-specific strategies and targets. The GWG meets, reviews the proposal and provides comments back, both through the Planning representative and a confirmatory memo. Where further modifications to the production targets become necessary, the process is repeated until resolution is achieved.

In one way, the delays and changes experienced with facility targets during the first years of SEP were beneficial. Such uncertainty, combined with cash-flow constraints, forced the development of flexible designs. Even where present production objectives may seem clear-cut, it is recommended that as much flexibility as possible be built into a facility. This is emphasized because in practice, few existing hatcheries have maintained their original objectives throughout their operating lifetime.

Step 2 - Senior-level Reconnaissance

When Phase I commenced, a number of enhancement projects had been well-researched and were ready to be implemented. However,

the majority of proposed projects[a] required further investigation to confirm their potentials.

Most of the major salmon-bearing areas of British Columbia have now been surveyed and reported on by bioengineering teams normally consisting of the New Projects Coordinator and a Senior Engineer. Whenever possible, the local Fishery Officers are asked to participate in these surveys and impart their additional local knowledge of the systems. These surveys initially were province wide, but more recently have focussed on those priority areas identified by the GWGs in their reviews.

These surveys preferably are done by helicopter. This is because the helicopter offers the speed and range to cover large areas quickly, yet allows close-up examination of any key features noted during the surveys. The surveys are meant to provide an overview, such that the most promising sites can be flagged for more intensive groundwork. Ideally, the reconnaissance team should survey the area four times.

The first general survey is undertaken preferably during a good weather and clear water period in the summer, as it is on this general survey that the team gains its orientation to the geography of the area.

During this and subsequent surveys, the following general information for the watersheds is noted:

- size of watershed (reflects water storage capacity)
- drainage pattern of watershed (eg, dendritic vs radial or parallel networks can indicate stability of subsurface geology)
- watershed topography (eg, low-lying terrain will result in more stable discharge patterns than steep terrain)
- number and size of lakes (buffer sediment load, temperature and magnitude of discharges)
- type and extent of vegetation (buffering effects similar to lakes)
- actual stream flow versus flood channel size and amount of meandering (indicators of stream stability)
- streambed materials, gradient, and amount of braiding (indicators of rearing and spawning potential)
- water color, turbidity, and temperature (water quality indicators)
- type, location and height of any obstructions or high-gradient sections (useful in defining limits to salmon distribution as

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[a] Project listings were developed by each of three GWGs (pre-SEP organization differed, in that each GWG had one or more representatives experienced in enhancement bioengineering).

well as potential for gravity supply[a] of surface water to a facility for fish or power)
- potential for groundwater (eg, springs and delta areas indicate potential; rock outcrops do not)
- competing resource activities in watershed (agriculture, logging, mining, industrial or urban development)
- location and type of human settlement (labor and logistical support potential)
- type and proximity of access to potential sites
- type (single-phase or three-phase) and proximity of power

Often, this first survey will result in the outright elimination of many systems from further consideration. For those systems still remaining, three more surveys should be scheduled for key periods of the year.

A spawning survey is timed to coincide with the peak spawning period of the key stocks in the area. The numbers and distribution of spawners are examined in relation to the physical potential of the habitat. Also, the vulnerability of adults to the various methods of capture is considered (ie, holding areas and potential fence sites are identified).

A winter survey should be undertaken during a period of extreme cold between December and February. This survey is particularly useful in identifying and measuring groundwater outflows. In addition, the team can evaluate potential problems associated with low winter flows, such as dewatering of redds or the impact of icing conditions on the winter operation of any proposed facilities.

A flood survey, mounted during the time of peak runoff, considers factors such as scouring or erosion, the extent of flooding on potential sites, and water turbidity. Depending on circumstances, this survey may be optional.

More recently, the bioengineering team often has been able to make only one joint survey, thereafter breaking into their specialist groups to do the remaining surveys. While in some ways this approach may be more efficient, I feel that both groups gain a far better understanding of the area, as well as of the other group's concerns, when the team participates in all four surveys.

Upon completion of these surveys, a formal memo report is prepared. This report summarizes the observations made and identifies those enhancement opportunities worthy of further feasibility studies.

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[a] A net head of 0.5 - 5.0 m within 0.5 km of the facility site is needed to economically develop an adequate gravity supply to a facility.

The final choice of site may be affected by intangible factors such as political initiatives; where such direction is evident, its impact should be assessed.

In preparation for the continuation of SEP beyond Phase I, various planning exercises have been undertaken. As part of these exercises, an Enhancement Opportunities Subcommittee (EOS) was formed to update the listing of enhancement opportunities. The EOS was made up of representatives from the BCFW, the Habitat Management Division of DFO, and the SEP Enhancement Operations, Engineering, Program Development and Special Projects groups. With the assistance of federal and provincial regional staff, the EOS compiled opportunity lists for each statistical area. The EOS also developed biological, engineering and economic standards, against which each opportunity was then rated (see Lill et al, MS 1983, for details of EOS procedures; a sample listing is provided in Appendix 3). These listings proved quite useful in preparing both general and reconnaissance program submissions for the continuation of SEP.

Step 3 - Feasibility Studies

Those systems and sites identified as having the best potential in the senior-level reconnaissance surveys are subjected to more intensive investigation by Engineering and the New Projects Unit. Such investigations, some of which may be done by either group (Table 2), are comprised of a number of components. In this report, emphasis is placed on those components for which the New Projects Unit takes responsibility.

Ground Inspections of sites should be undertaken jointly with Engineering. They are done in order to obtain additional overview information on site topography, available head, feasibility of access, type of vegetative cover and amount of merchantable timber, soil types and rock outcrops, groundwater seepages, utilization by wildlife, etc.

Biological Baseline Studies can be divided into two major activities: collation of existing data and generation of new data through fieldwork. Initially, the New Projects Unit attempted to collate all existing data of biological value in further bioreconnaissance and facility planning into 'backgrounder' reports. These reports were generated by the Unit's Data Analyst, and temporary help such as summer students. To enable relatively inexperienced staff to cover all potential data sources for each watershed effectively and consistently, a 'Primary Sources Manual' was compiled, which listed key references and contacts by agency and type of information. This manual is kept in looseleaf form to facilitate continuous updating. Only a few backgrounders were formally completed (Helm et al, MS 1980a and MS 1980b; MacDonald and Shepherd, MS 1983), due to a lack of manpower and to midstream switches in project priorities for various reasons -- one example of the latter being the moratorium imposed in 1979 on Nechako River

Table 2. Feasibility studies required for development of a SEP facility (in approximate chronological order).

Type of Study	Minimum Duration	Responsibility		
		New Projects	Engineering	Other
Ground Inspections	1 wk	X	X	
Biological Baseline Studies	1-2 yr	X		
Aerial Photography	3 mo		X	
Authority to Enter Land			X	
Ground Control Survey			X	
Topography Mapping			X	
Economic Overview			X	X
Surface water Monitoring	1 yr	X	X	
Groundwater Potential	1 mo		X	
Establish Access	variable		X	
Test Well(s)	2 mo		X	
Groundwater Monitoring	1 yr	X	X	
Alternate Site Analysis	6 mo		X	
Acquisition/Zoning of Land	6 mo		X	X

enhancement, until Departmcntal concerns with the Kemano II hydro-electric project had been resolved. It is still felt that this type of review would be well worth undertaking, in that it could improve planning and avoid duplication of fieldwork. Unfortunately, continuing constraints in both manpower and timeframe have forced the Unit into only cursory and informal reviews of key data items, which are gathered in New Projects central files, and incorporated into contract specifications for proposed fieldwork. Also, this type of review activity has been increasingly requested as part of consultant biobaseline studies (see below).

With respect to fieldwork, New Projects staff themselves now undertake only minor reconnaissance efforts due to manpower constraints. The majority of biobaseline studies are done through contracts with consultants, BCFW, or through other government programs such as Job Creation. There are definite drawbacks to this approach, such as the loss of in-house staff expertise in fieldwork and local knowledge. Also, the government contracting-out process is lengthy (see outline in Table 3), making it essential to establish an effective working relationship with the Department of Supply and Services (DSS). Various other steps have been taken to streamline contracting procedures, such as standardization of contract specifications (Appendix 4) and the use of word processors.

Depending on the situation, the field studies can incorporate general biophysical reconnaissance for adult and juvenile phases, as well as site-specific feasibility work. Appendix 4A gives a general outline of program specifications as currently requested by Enhancement Operations staff.

Initially, much effort went into attempting to estimate juvenile and adult populations accurately, and to collect and rear fry for coded-wire tagging. These program components were expensive and often conflicted with other program objectives, such as definition of the distribution and duration of rearing. For the purposes of facility design, the start/peak/end dates of the wild fry migration are crucial; accurate enumeration of wild fry populations is needed only where facility fry may be outplanted for final rearing. Similarly, adult migration timing is critical; highly accurate numbers of spawners are no more useful than knowing whether past estimates by Field Services can be used to project average availability of broodstock (to date, independent fishery officer estimates have most often ranged from one-half to equivalency with study estimates). Coded-wire tagging of juveniles is of no direct use to facility design, but was included to provide information on stock contributions to fisheries. The first tag returns from wild stocks that had been pen-reared to taggable size were very poor, and management biologists requested that all such tagging programs be terminated. Elimination of these items

Table 3. Flow chart for contracting out of New Projects biobaseline studies (assuming juvenile downstream migration monitoring required).

Activity	Group[b]	Completion Date
Final selection of study streams	NPU	Nov. 1
Collection of background stream data	NPU	Nov. 15
Design of studies and development of RFP[a]	NPU	Dec. 1
Drafting and typing of RFP specifications	NPU	Dec. 15
Requisition preparation and signature authority to $100,000 level	NPU	Dec. 21
Preparation of RFP and mail-out	DSS	Jan. 1
Bidder preparation of proposal; tender closure	CON	Jan. 21
Evaluation of proposals and bidder selection	NPU	Feb. 15
Negotiation with successful bidder; Ottawa DSS approvals	DSS	Mar. 15
2 wk mobilization; fieldwork begins	CON	Apr. 1

[a] RFP = Request For Proposal

[b] NPU = New Projects Unit
DSS = Dept. Supply & Services
CON = Consultant

resulted in cost savings and allowed coverage of additional systems.

Further logistical and cost savings have been possible, both by consolidating neighbouring systems into a regional study package and by coordinating with other groups where possible. An example of the latter is the addition of an adult coho sampling component to a North Thompson juvenile tagging program undertaken for Field Services by a Job Creation crew. To maximize savings through joint studies requires good communications during planning of fieldwork. Because effective communication is difficult in a large and diverse organization such as DFO, the New Projects Unit encourages production of the 'Fieldwork Bulletin' as a regular update on the reconnaissance plans and activities of the various arms of DFO and BCFW.

At least two years' adult and juvenile data should be collected in order to allow some evaluation of variation between years.

To ensure effective biobaseline contract supervision despite manpower constraints, the New Projects Unit has at times contracted with companies to provide technical monitors (for contract specifications, see Appendix 4B).

A list of the biobaseline reports generated for the New Projects Unit to date is provided in Appendix 5.

Water Quality Monitoring of both surface and groundwater sources is done for at least one full year by New Projects Unit staff. Where possible, sites are geographically grouped, and sampling circuits are undertaken four times over the year. During each visit to a site, a 'hatchery series' water quality sampling is done (see Table 4 for parameters sampled and culture limits; Appendix 4C outlines methods). In addition, a three- or six-month thermograph (generally a submersible model such as the Peabody-Ryan J-90 or J-180) is installed on the first trip and serviced on succeeding trips. Where there is any concern regarding the dissolved gas content of the water, the source will be measured at least once using a tensionometer and an oxygen kit. On every visit, water temperature and pH are measured with a calibrated pocket thermometer and Hach kit.

Where wells are developed by Engineering specifically for enhancement facilities, another water quality sampling sequence is followed. In general, each well is pumped at a minimum 1200 LPM over 96 hr and sampled every 24 hr. Although New Projects Unit staff did all sampling at first, manpower constraints coupled with scheduling uncertainty dictated that the on-site sampling and shipping be contracted out. Appendix 4C outlines the specifications used for that contract. Equipment normally used for

Table 4. Water quality parameter screening table (taken from Sigma, 1983).

CAUTION:
The levels in this table are not criteria; they are intended only to indicate which of the parameters in a water analysis require closer examination and comparison with detailed criteria. Notes outlining the rationale for establishment of the screening levels are given following the table.

Fish Culture Parameters	Recommended Screening Levels[1]	Metals	Maximum Acceptable Levels(ug/1)
Alkalinity[2]	G 15 mg/1 as $CaCO_3$	Aluminum (total)[12]	100
Ammonia (total)[3]	L 0.05 mg/1 as N	Cadmium (dissolved)	0.3
Carbon Dioxide[4]	L 10 mg/1 CO_2	Chromium (total)	40
Dissolved Oxygen[5]	G 11.2 mg/1 O_2 and G 95% saturation	Copper (dissolved)	2
		Iron (total)[12]	300
Hardness[6]	G 20 mg/1 as $CaCO_3$	Mercury (total)	0.2
Hydrogen Sulphide (total sulphide)[7]	L 0.002 mg/1 as H_2S	Manganese (total)[12]	100
Nitrite[8]	L 0.015 mg/1 as N	Nickel (total)	45
pH[9]	7.2 to 8.5	Lead (total)	4
Temperature[10]	5 to 10°C	Selenium (total)	50
Total Gas Pressure	L 103%	Silver (dissolved)	0.1
Suspended Solids[11]	L 3 mg/1	Zinc (dissolved)	15

NOTES TO ACCOMPANY TABLE 4

1 G = Greater than; L = Less than

2 This is a suggested minimum level of alkalinity to buffer pH changes in rearing ponds.

3 The total ammonia concentration of 0.05 mg/1 as N, at pH 8.5 and T = 18°C, gives an unionized ammonia concentration of 5 ug/1 NH_3-N. This value is 50% of the maximum recommended level and therefore allows for an ammonia increase within the hatchery.

(Table 4 continued)

4 The recommended screening level allows for an increase in carbon dioxide within the hatchery.

5 A screening level of 11.2 mg/l O_2 corresponds to the most stringent dissolved oxygen criteria for hatchery operation. This is the minimum acceptable concentration for incubation of eggs just prior to hatch at a temperature of 10°C. The dissolved oxygen levels in any water source should also be examined closely if saturation is depressed below 95%. The causes of the DO drop from equilibrium and the potential for further DO depression should be investigated.

6 This is a suggested minimum level of hardness to reduce risks of toxic effects of metals, low pH and poor fish health. Although insufficient data are available to establish specific criteria for hardness, the importance of hardness (the divalent metallic cations Ca^{2+}, Mg^{2+} and others) in reducing the toxic effects of metals, low pH, total gas pressure, and nitrite has been documented.

7 Hydrogen sulphide is detectable by sense of smell at much lower concentrations than the recommended level.

8 The recommended level assumes that the chloride concentration is very low, thereby maximizing the toxicity of nitrite.

9 A minimum inflow pH of 7.2 makes some allowance for the pH reduction due to CO_2 respiration in a rearing pond. Inflow pH criteria should be evaluated on a site-specific basis with consideration of alkalinity, free CO_2 and fish loading density.

10 This is the safe temperature range for incubation of sensitive species to both high and low temperatures.

11 The characteristics of the suspended solids should be carefully considered. For example, some materials (ie iron hydroxide precipitates) are toxic at lower concentrations than 3 mg/l.

12 Analyses for total aluminum, iron and manganese frequently result in high metal concentrations (exceeding the screening levels) if the water sample contains a significant quantity of suspended silt or clay. These mineral forms of the metal are essentially non-toxic. However, aluminum, iron and manganese precipitates are toxic. Their presence should be investigated if the total metal levels are high and the inert mineral fraction of the suspended solids appears to be relatively low.

on-site sampling includes an ASTM standard reference mercury thermometer, a tensionometer, a barometer, an iodometric kit or membrane electrode meter for oxygen, a pH meter (with glass electrode), and a conductivity meter. Considering the costs involved in mounting a pumptest, it is essential that backup equipment be readily available. At the same time that water quality is tested, aquifer yield is evaluated by a consultant hydrogeologist under contract to the Engineering Division.

The more stable water quality parameters are evaluated at the Pacific Region Laboratory, which is located in West Vancouver and jointly financed by the Departments of Environment and Fisheries and Oceans. Samples are delivered to the lab within 48 hr of being taken.

Upon receipt of data from the lab and consultant, the New Projects Unit summarizes the results and determines the suitability of the supply for salmonid culture. Three types of memo reports are routinely provided. The first summarizes the results of the initial sampling visit, providing logistical details as to location of sampling and thermograph, and first-cut interpretation of water quality (is it worth continuing or expanding monitoring at this site?). The second reports on the suitability of the water source at the conclusion of one year's monitoring. The third collates and interprets pumptest results. In all cases, a standard format is used. Appendix 6 provides an example of each type of report.

The interpretation of water quality data can be likened to a tightrope act. If the analyst does not properly weigh the impact of each parameter as well as synergisms, two types of costly errors can result. If the water supply is deemed acceptable and is not, a facility can be built that will suffer poor production and costly water treatment retrofits. On the other hand, if an overly conservative approach is taken, sites that are actually suitable may be rejected, resulting in additional and unnecessary reconnaissance costs to identify new sites. Because of the importance of accurate water quality criteria, this subject has been reviewed and recently updated (Sigma, MS 1979 and MS 1983). Information on water quality criteria continues to accumulate at rapid rate, and regular updates of the criteria are recommended. It should be emphasized that the limits specified in Table 4 are conservative and are used to screen sample parameters rapidly but thoroughly. Any parameter which falls outside the specified limits is flagged for detailed determination of the <u>site-specific</u> acceptable level.

Where water quality is deemed marginal, a pilot operation is advised (see section on pilots). For example, temporary facilities were constructed in Phase I of SEP at Mathers Creek to examine the effects of marginally high levels of un-ionized ammonia, at Chehalis River to examine low hardness levels, and at Fort St.

James to check marginally high iron levels.

In terms of the various feasibility studies identified in Table 2, the final point to be made is that the biological baseline and water quality monitoring studies require the greatest amount of time to complete, and they are seasonally inflexible. Where projects must be 'fast-tracked' for financial or other reasons, the resulting substandard data base imparts costs in higher-risk and overly-conservative designs. Similar problems will occur where funds for basic planning are not provided in advance of funds for construction.

Step 4 - Biological Design

Biological Criteria

The key operating words for this task are consistency and documentation. The New Projects Unit continues to accumulate all relevant data regarding biocriteria. As new data become available, or where disagreement becomes apparent among the biological staff, the Unit will canvass the Enhancement Operations group (and outside agencies, if appropriate) by mail and telephone, or meeting, in order to produce a consensus approach. Where necessary, that consensus is summarized and distributed back to the group in a memo report. The assumptions and criteria used are always detailed in each facility design memo (see next section), to ensure all participants are aware of the design's constraints.

Criteria for containers commonly used in the production-scale enhancement facilities are summarized in Table 5 and Figures 3 to 5. Detailed design specifications will be catalogued in a future report. Relative merits of various container types are listed in Table 6.

Larger research projects have been handled either by staff from other units (eg, aeration studies done by the South Coast Unit in conjunction with Engineering--see McLean and Boreham, MS 1980), or by contract (eg, review of adult return information in relation to juvenile outplanting techniques--see Lister et al, MS 1981).

Survival standards for Phase I (Appendix 7A) were developed in 1979 by a committee of senior staff using the best data available. Revisions were made up to 1981 on an ad-hoc basis. For the 1982 SEP continuation planning exercise, the EOS reviewed the survival standards, and generated a more comprehensive listing by species and technology (Appendix 7B). At the time that SEP Continuation planning was proceeding, it was recognized considerable existing data could be used in the generation of biostandards. However, it would require a major effort to incorporate these data, as most were not easily accessible or comparable. The Ad Hoc Biostandards Working Group, which consists of representatives from the concerned branches of DFO, was formed in 1982 to work towards documenting and updating the biostandards information base.

Table 5 Criteria for standard units used in salmon culture in British Columbia

UNIT TYPE	TYPICAL KEY DIMENSIONS[a]	SPECIES[b]	UNITS/ LINE	FLOW RATE	LOADING RATE	COMMENTS
A. INCUBATION						
Modified Atkins Box	2 cells/box, each cell 835L x 365W x 315H/250D (55H plenum); box 2010L x 435W x 315H overall;	CM	2 boxes (stepped)	30 LPM/ line	150K eggs/cell 600K eggs/line	- Welded aluminum construction; cement blocks used as stands - Need clean water
Keeper Channel	2000W x 450H/200D x 22000 between breaks; slope 1:250 to 1:500; single layer of 50 dia gravel; 150-300 drop @ breaks	CM (CN)	up to 2 without auxiliary aeration	150 LPM @ start; 450 LPM @ end (per line)	SP / eggs/m^2 CM / 15K CN / 8K	- Cement construction - Need clean water - Channel cover required - used for CN @ Robertson only
Heath Tray	Egg space in tray 390L x 320W x 50D (6200 cc); 8-tray stack with stand 630L x 620W x 810H (outside dim.)	CN CO (CM) (PK)	8 trays/ stack	15 LPM/ stack routinely; 19 LPM/ stack for flushes	SP / Eggs/Tray CN / 5K CO / 8.5K CM / 9K PK / 16K	- Used at dirty-water stations - PK/CM eggs removed prior to hatch and placed in substrate incubators; CN/CO to ponding - Central or wall-mounted headers - Arranged two stacks high (but separate water supplies)
Freestyle Box	Egg space 790L x 615W x 430D; box outside dim. 1000L x 625W x 510H, incl two 90W headers and 80H plenum	CM (CN)	up to 6	CM 30-40 LPM/line CN 32 LPM	SP / eggs/box CM / 500K CN / 300 - 330K	- simple fabrications - need clean water - used for CN @ Robertson only
Keeper Box	2650L x 1150W x 1000H (outside); 1350L x 1000W x 400 gravel depth, 200H plenum	CM	separate supply to each box	40 LPM @ start; 60 LPM @ end	150K eggs/box	- Aluminum or fiberglass construction - In clean water, can incubate to hatch on screens in box; in dirty-water, used only for hatch-emergence period - Backflush port for cleaning

[a] L = length; W = width; H = height; D = water depth; S = slope; DIA = diameter; RAD = radius. Dimensions in mm unless otherwise specified.
[b] CO = chum; CM = chum; CN = chinook; PK = pink; SK = sockeye; parentheses indicate use is not common.

(Table 5 continued)

UNIT TYPE	TYPICAL KEY DIMENSIONS[a]	SPECIES[b]	UNITS/ LINE	FLOW RATE	LOADING RATE	COMMENTS
Quinsam Box	1220W x 1220H x 1220 - 1830L (variable) gravel depth ~ 500 (750 with pea gravel)	PK	separate supply to each box	180 LPM/ box	max of 750K eggs/box (1830L)	- Water supply via manifold/pea gravel system - Aluminum construction - Clean water preferred but back-flush port provided
Spawning Channel	12000W max x 1500D; gradient 1:500-1:1000; side slope 1.5:1 - 2:1; gravel size range 20 - 150, depth 450 - 600; water vel. 45 - 75 cm/sec.	SK PK CM	Areas range 2200-3180m^2 (upper limit not determined)	0.19 CMS/ m of width	1.25m^2 spawning pair	- Settling basing upstream of channels on dirty rivers
B. REARING	**(Exchange rates generally to meet or exceed 1.5 x /hr)**					
Raceway	4000W x 22000L x 1000 - 1700H/700D; slope 1:250	CN CO CM	2/line (44000)	adjust so O_2 meets Davis 'B', eg	CM 15K fry/m^2 OR	- Greater depths used for adult holding - Lower ends of CM keeper channels can be flooded for start-up feeding in severe climates - Fry normally reared to 1g max CM; 5g CN; 20-25g CO
				fry(g) / °C / kg/LPM / kg/m^3		
				0.5 / 5 / 1.0 / 11.6		
				15 / 0.2 / 4.2		
				25.0 / 5 / 1.9 / 23.3		
				15 / 0.5 / 8.2		
				(at ration level of 90% of max)		
Burrows Ponds	15000 - 23000L x 2400W/leg (5200W overall) x 1200H/760 - 900D	CO CN	(as per raceways)			- design details as per Burrows and Chenoweth (1970)

[a] L = length; W = width; H = height; D = water depth; S = slope; DIA = diameter; RAD = radius. Dimensions in mm unless otherwise specified.
[b] CO = chum; CM = chum; CN = chinook; PK = pink; SK = sockeye; parentheses indicate use is not common.

(Table 5 continued)

UNIT TYPE	TYPICAL KEY DIMENSIONS[a]	SPECIES[b]	UNITS/ LINE	FLOW RATE	LOADING RATE	COMMENTS
Pallant Seapen	9000L x 9000W x 3000H/2000D main net of 13mm (stretch) knotless nylon; also quarter-size fry introduction nets of 3mm knotless nylon; 12mm pen frame lines; 12 x 15 kg weight hung inside of main net to prevent billowing	CM (PK) (CO)	3-pen units 2m between pens; 10m alleys between units	N/A; but site should be well-flushed, 10-30 ppt salinity	400K fry/pen or 3 kg/m^3 (CM); up to 5 kg/m^3 (CO).	- 'Topper' floats used to date; - CM/PK Fry reared from button-up to 2g in pens; CO transferred to pens @ 10g+. - pink reared at Pallant and in various experimental pens at Quinsam. - coho pens attempted in Indian Arm.
Earthen Channel	Up to 100000L x 3000W (btm) x 1600H/1000D side slope 2:1	CM CN CO	routinely 100 max L	(as per raceways)		- Tlupana channels have no lining, lose ~0.05 CMS through permeability.
Capilano Trough	6550L x 950W x 600H outside dim; sides rounded at btm (300 RAD); 6400L x 800W x 475D inside dim.	CN CO (CM)	2 (stepped)	120 start 240 end	115 kg/trough max.; intitial loadings 40 K CN or 55K Co/trough	- aluminum or fibreglass - primarily for start-up rearing to 2g or less
Circular Tubs	3250 DIA x 1280H outside dim; 3050 DIA x 910D inside dim; btm slopes to center standpipe (100 cm inner pipe surrounded by 200 cm slotted/screened outer pipe)	CN CO (CM)	1	(as per raceways)		- jets on vertical submerged header pipe promote circular flow - some sites have water level control via standpipe tied into drain at outer edge of tub (more accessible)
C. ADULT HOLDING						
Various of Rearing Containers	Special depth requirements of 2000H/ up to 1700D.	CM CN CO (PK)	-	1.2 kg/LPM	32kg/m^3 long-term; 64 kg/m^3 short-term (for CM only)	- short-term = 1-2 days - special containers for adults holding required only at facilities dealing mainly with species reared for full year.

[a] L = length; W = width; H = height; D = water depth; S = slope; DIA = diameter; RAD = radius. Dimensions in mm unless otherwise specified.
[b] CO = chum; CM = chum; CN = chinook; PK = pink; SK = sockeye; parentheses indicate use is not common.

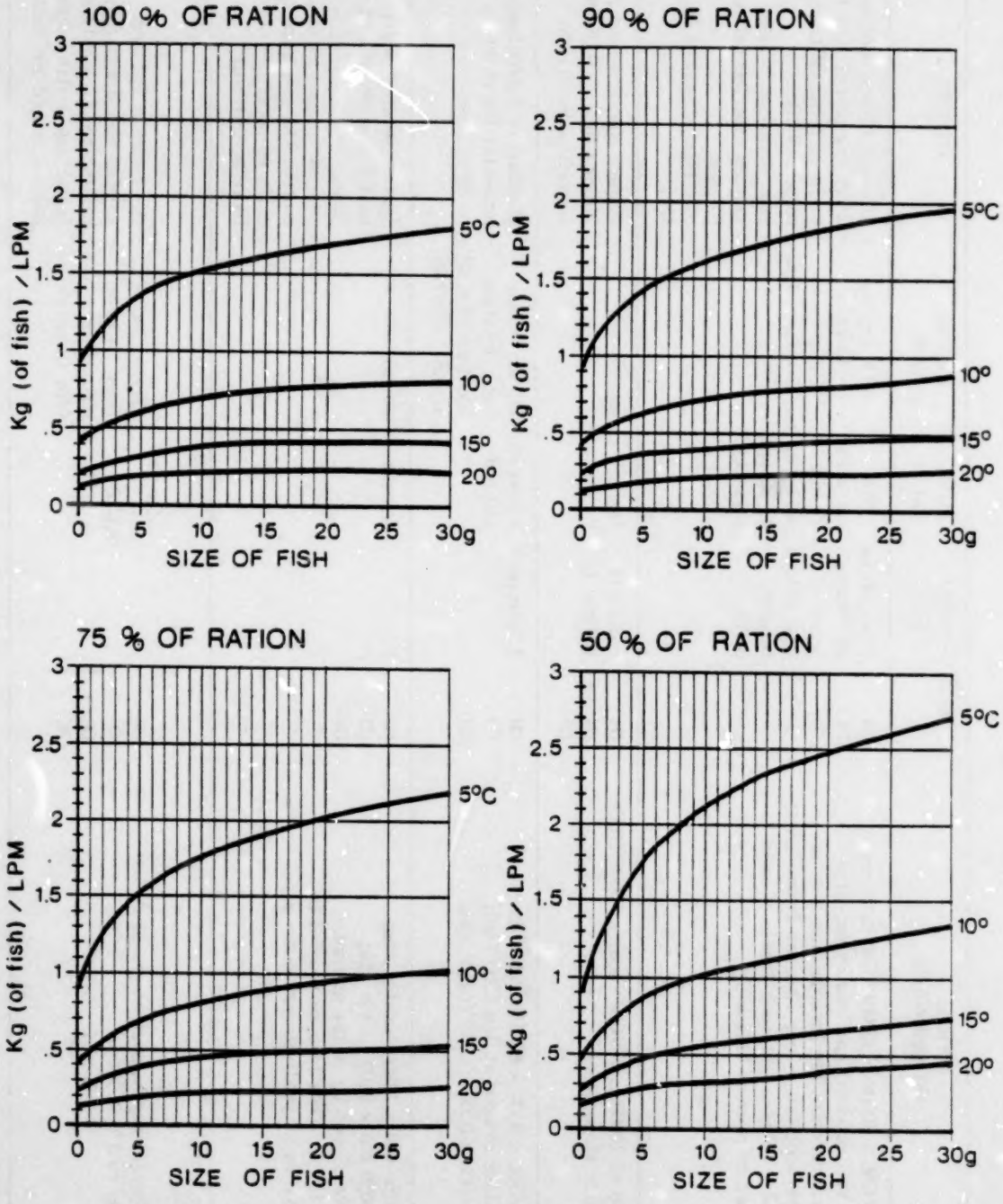

Figure 3 Flow loading criteria over the temperature range and at four ration levels commonly used in design of SEP Phase I facilities (see Appendix 10 for program details).

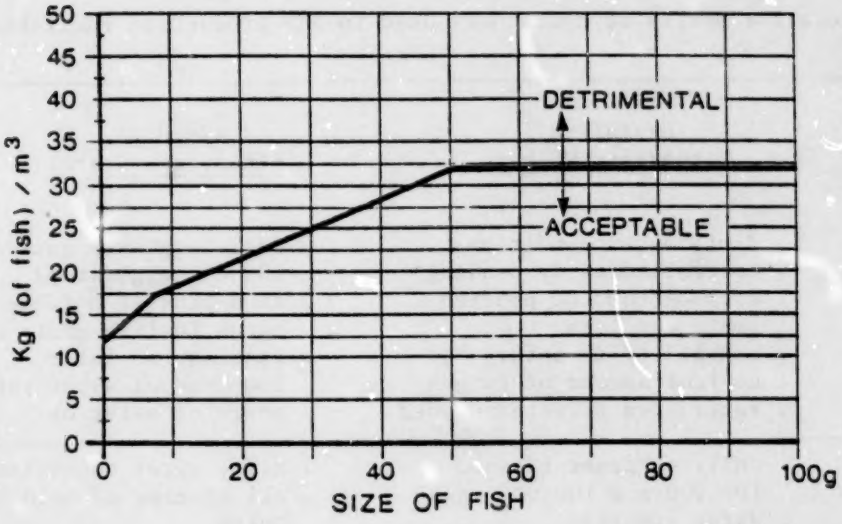

Figure 4 Volume loading criteria used in design of SEP Phase I facilities (see Appendix 10 for program details).

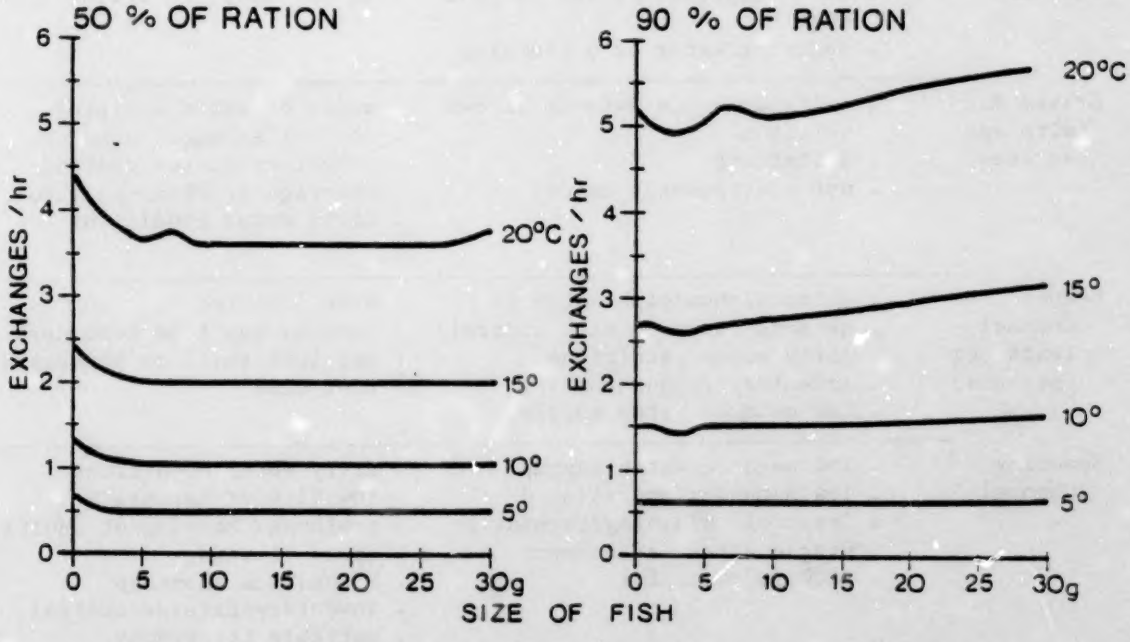

Figure 5 Exchange rates for two ration levels, as calculated from the interrelationship of flow and volume criteria (see Figs 4 and 5).

Table 6. Relative merits of containers used in SEP production facilities.

Type of Container	Useful in Situations Where:	Avoid in Situations Where:
INCUBATION:		
Vertical Tray	. dirty water conditions . controlled/early ponding . chinook/coho to ponding . small egg lots . control of inventory . . control spread of fungus . reaeration of water needed	. daily eggtakes exceed 100,000 eggs/stock . chum/pink if held beyond hatch (unless media added) . shortage of labor . low head on water supply . space or water or $ limiting
Modified Atkins Box	. daily eggtakes between 100,000 and 500,000 eggs . water limiting	. dirty water conditions . all species of held beyond hatch . small egg lots . rapid spread of fungus
Bulk Box	. daily eggtakes exceed 500,000 eggs . space or water or $ limiting	. as for modified Atkins boxes
Gravel Box (with egg screens)	. all species to swim-up at own volition . $ limiting . not continuously manned	. space or water limiting . controlled/early ponding . inventory/fungus control . shortage of clean-up labor . dirty water conditions
Keeper Channel (with egg screens)	. chinook/chum/pink hatch to swim-up (some ponding control) . dirty water conditions . inventory/fungus control . low head on water supply	. area limiting . channel can't be kept dark . egg lots small or separated over time
Spawning Channel	. low head on water supply . low manpower/operating $. 'natural' spawning/incubation . single stock enhancement . sockeye/chum/pink	. dirty water conditions . low flow or capital $. prolonged holding of adults . space limiting . broodstock shortage . inventory/disease control . variable topography . rearing required

Table 6 (cont'd.)

Type of Container	Useful in Situations Where:	Avoid in Situations Where:
REARING: Capilano Trough	. small lots (stock/timing differences) . early rearing; chinook/coho ponding to 2 g . space or water limiting . temporary siting (pilots) . 'piggy backing' of species . low water °C during ponding . inventory control . feeding/cleaning control . fish transfers necessary	. few, large groups . input water marginal in quality . labor or operating $ limited . no cover available . rearing beyond 2g . disease triggered by stress of crowding . low head on water supply
Concrete Raceway (Shallow)	. rearing to 60g+ . inventory control . feeding/cleaning control . few, large stocks	. water or capital $ limiting . temporary siting (pilots) . stock or timing separation into small lots . no slope
Concrete Raceway (Deep)	. as per shallow raceway . adult holding	. as per shallow raceway . cleaning more difficult
Modular Aluminum Raceway	. as per shallow raceway . temporary siting (pilots) . medium-large groups of fish	. as per shallow raceway . low head on water supply
'Aqua-Breeder' (Vinyl Liner)	. as per modular aluminum raceway	. as per modular aluminum raceway, but shorter lifetime
Circular Tubs	. no slope . small groups of fish . low manpower (self-cleaning) . flows limiting (recirculation) . velocity control . inventory control . short-term rearing	. input water marginal in quality . low head on water supply . disease problems . routine mechanical crowding
Above-ground Swimming Pool (vinyl liner)	. capital $ limiting . pilot/experimental . short-term rearing . no slope . small-medium groups . inventory control . low flows	. permanent site . input water quality marginal . labor limiting (manual cleaning) . low head on water supply . disease problems . heavy loading (variable circulation)

Table 6 (cont'd.)

Type of Container	Useful in Situations Where:	Avoid in Situations Where:
Burrows Pond	. medium-large production groups . flows limiting . heavy loading (uniform circulation; self-cleaning . inventory control	. input water quality marginal . capital $ limiting . disease problems . routine mechanical crowding . variation in loadings (flow set by hydraulics)
Earthen Channel	. large production groups . smolt quality paramount . low head on water supply . direct release of fish	. flows or space limiting . no slope/irregular topography . cleaning/inventory control . disease/predator problems . fish transfers necessary . porous subsoils . no bank maintenance
Floating Cages	. short-term rearing . space on land limiting . flows limiting . low capital $. saline water required . medium size production groups	. low ambient O_2 . poor flushing circulation . exposure to storms . high/fluctuating temperatures . disease problems . fouling/predator problems . maintenance $ limiting . inventory/feed control . potential pollutants (eg, marinas)

Biological Design. For each facility design, the New Projects Unit issues a standardized memo report outlining the biological needs for the operation of that facility. Each memo report requires certain key site data in addition to general criteria (Table 7). The memo serves the following functions:

- defines targets and enhancement strategy
- formulates incubation and rearing programs
- documents assumptions, criteria, and rationale used to formulate the programs
- outlines the physical requirements that Engineering has to provide to achieve the biological objectives.

In general approach, the calculation system parallels that used by Kramer, Chin and Mayo Inc. (see pp 54-55 of Piper et al, 1982 for an overview). The biological design report for Tenderfoot is appended as a detailed example (Appendix 8). The calculation sequence takes the following steps:

(1) Calculate the numbers of fish of each species and stock required at each life stage, in order to meet the defined production objectives and strategies. For the most part, the survival standards contained in Appendix 7 are used for these calculations. Calculation of the needed number of brood stock requires additional input of the male: female eggtake ratio (generally 3:5) and an estimate of pre-spawning mortality from site-specific data.

(2) Define the start point for each species and stock, using average adult spawning timings from available field data.

(3) Define the end point for each species and stock, using average smolt migration timings from field data.

(4) Determine the seasonal temperature profile, using average monthly temperatures for each water source used in the facility.

(5) Calculate the number of incubation containers and the associated flow, using standard loading criteria (Table 5).

(6) Estimate the duration of incubation from the temperature profile and the prediction methods given in Table 8.

(7) Forecast the growth of fish through the rearing period. This is done using an in-house computer program called 'GROWTH TIMING' which is based on a model developed by Stauffer (MS 1973) and modified by McLean (MS 1979). This program, with inputs of water temperature, fish size and ration level, computes weight at five-day intervals (Appendix 9). If fish must be released at a specific

Table 7. Key information elements required to complete biological design calculations for SEP facilities

	KEY INFORMATION ELEMENT	SOURCE	FOR DETAILS, REFER TO
1.	SPECIES AND STOCK PRODUCTION TARGETS	GWG	p 11
2.	ENHANCEMENT STRATEGY TO BE USED	Senior-level Bioengineering	pp 11 - 14
3.	SURVIVAL RATES FOR SPECIES, STOCK, AND STRATEGY	Biostandards	Appendix 7
4.	SPECIES AND STOCK CHARACTERIZATION a) Start-peak-end timing of adult entry/spawning b) Adult distribution, sex ratio, age composition, and fecundity c) Start-peak-end timing of juvenile migration(s) d) Juvenile rearing history/distribution e) Disease sampling of all stocks	On-site Fieldwork	pp 14 - 18
5.	SEASONAL WATER QUALITY AND TEMPERATURE	Monitoring Program	pp 18 - 22
6.	TIMING CRITERIA BY LIFE STAGE (eg. adult holding, incubation to hatch, etc.)	ATU Predictions; 'Growth' Program	p 31, 33 pp 31 - 34; Appendix 9
7.	LOADING CRITERIA BY LIFE STAGE AND CONTAINER a) Volume - container numbers b) Flow	'Bio-Load' Program; Standard Criteria	pp 23 - 34; Appendix 10
8.	SUPPORT REQUIREMENTS	Fieldwork and Operations Staff	pp 34 - 35

Table 8. Methods used to predict duration of incubation phases for SEP facilities

SPECIES	EYED STAGE	HATCH STAGE	EMERGENT STAGE
CHINOOK	280 ATU	480 - 540 ATU	900 - 1000 ATU
CHUM	300 - 350 ATU	475 - 525 ATU	900 - 1000 ATU
COHO	220 ATU	400 - 500 ATU	700 - 800 ATU
PINK	350 - 400 ATU	550 - 650 ATU	900 - 950 ATU

NOTES:

(A) ATU = Accumulated Thermal Unit. Calculated as the number of degrees Celsius over 0°C that the mean daily temperature is, summed over the number of days. For example, 2 days @ 5°C + 3 days @ 7°C is (2x5) + (3x7) = 31 ATU

D = time in days

T = mean temperature for period in °C

(B) More accurate predictions may be possible in the future with the incorporation of a Q_{10} effect, resulting in an equation of the general form $\ln D = aT+b$, where D is time in days and T is mean temperature for period in°C (MacDonald and Shepherd, MS 1982).

size and date, and if water temperatures can be manipulated, then the program can be re-run with altered temperature and ration levels until the release targets are achieved.

(8) Calculate the numbers of rearing containers and their associated flows. For early rearing, standard loading criteria (Table 5) are used. For rearing beyond 1-2g, an in-house computer program called 'LOAD RATE' is used (see Figures 3-5 and Appendix 10). This program bases flow loading rates on work done by McLean (MS 1979); volume loading rates are based on the curve provided by Mayo (1971), against which existing data from B.C. facilities had been checked and found to fit well. Water temperature, species, inflow and outflow oxygen levels, fish size, and ration level must be defined. Normally, volume and flow requirements are minimum at the start of rearing and maximum at the end--but not always. For example, coho reared for a full year on a surface water supply will often show a peak flow demand in the late summer warm-temperature period. Therefore, where rearing is prolonged and temperature is variable, a monthly tabulation of requirements is necessary.

(9) Calculate adult holding volume and flow requirements, using standard criteria (Table 5). In most cases, the containers for short-term rearing species are available and of adequate size to handle brood stock requirements.

(10) Tabulate total water demand on a monthly basis.

(11) Outline support requirements. This is a list of structures and equipment felt essential to the successful operation of the proposed facility. Table 9 can be used as a checklist to ensure inclusion of all major components required for a project.

Wherever possible, flexibility in design is used, so that future changes in production strategies can be accommodated. This translates into the use of species-interchangeable containers of standard dimensions as much as possible, considering the possibility of expansion at the same time as the initial design, and other such similar approaches.

The above calculation procedures are used by the New Projects Unit for salmon only. Where trout are included in a facility, the Fish Culture Section of BCFW is requested to provide the biological requirements for these species in a compatible format. These requirements are then integrated by New Projects into the biological design memo (see the Kitimat example in Appendix 8).

Table 9. Potential components of a SEP facility.

SITE:	SERVICE:
Land	Food Storage (Freezer/Cooler)
Access	Wet Laboratory
Main/Backup Power Generation	Dry Laboratory
Communications System(s)	Special Research Needs
Landscaping	Workshop
PROCESS WATER:	Mechanical/Electrical Room
Main Supply	Dry/Volatile Storage
Secondary Supplies	Equipment/Vehicle Storage
Intake/Pumping Facilities	
Distribution System	ADMINISTRATION:
Settling/Filtration System	Offices/Sleeping Room
Temperature/Water Quality	Lunchroom
Modification of Supply Water	Mudroom/Staff Lockers
Aeration Tower	Staff Washrooms
Water Re-use System	Public Washrooms
Flow Meters	Lobby/Reception
Effluent Waste Treatment	Public Display/Viewing Facilities
BIOLOGICAL PROCESSES:	HOUSING:
Incubation Area	Crew Residence
Incubator Wash/Pick Area	Manager's Residence
Initial Rearing Area (Covered?)	Asst. Manager's Residence
Feeders	
Final Rearing Area	CONTROL:
Fry Marking Area	Alarms - Water Flow
Juvenile Transfer Structure	" - Water Level
Juvenile Release Structure	" - Fire
Fish Transport Equipment	" - Security
Adult Fishway/Trapping	Fencing - Traffic Direction
Equipment	- Security
Adult Sorting/Holding Structures	- Predator
Eggtake/Decontamination Areas	Fire Stations
Offsite Holding/Rearing	
Facilities	

Step 5 - Bioengineering Concept Review

The New Projects Unit distributes copies of the completed biological design memo to various participants for review and comment before or during a review meeting. Copies go to the Engineering staff involved with the project and to a biological advisory group. Normally, the latter group consists of the New Projects Design Biologist and Coordinator, the Support Biologist and Unit Head of the appropriate Operations Unit, a facility manager, and the Chief of Enhancement Operations. Where trout are involved, the BCFW Fish Culture Section also participates. Similar to the conclusion of Jeppson and Taylor (1981), we have found it most valuable to have a facility manager appointed as early in the process as possible. Where this is not possible, the next best approach is for the Operations Unit Head to appoint the manager of an existing facility as advisor to the project. The selection rationale for such appointments has been variable, ranging from providing a training experience, to familiarity with the geographic location or technology involved. It is an inherent assumption that the appointee will ask the advice of other managers when he feels his experience to be lacking.

The New Projects Unit was set up specifically to act as the biological focal point for bioengineering communication; advice coming solely from the New Projects Unit has been deliberately minimized in favor of a consensus approach. Like Fox (1976), we feel that the best way to mesh design criteria and operational reality is to involve the operators at as early a stage as possible, so as to maximize understanding of and commitment to the probable operational mode. Use of this approach forestalls much of the "Why Does It Have to be This Way?" syndrome that has been discussed by Klontz (pers. comm., 1981 Northwest Fish Culture Conference). In addition, this approach also aids in reducing the risk of operating errors by facility staff during start-up.

Where members of the biological advisory group disagree as to any aspect of the proposed design, further discussion within the biological group is arranged by the New Projects Coordinator. When the group cannot reach a consensus, the issue is decided by the New Projects Coordinator in consultation with the Chief of Enhancement Operations. It should be emphasized that where arbitrary decisions are required, it is important that those decisions and their rationale be documented to ensure staff understanding.

Steps 6 and 7 - Site Layout and Flow Schematic Plans, and Concept Finalization

These plans are prepared by the Engineering Division and submitted in duplicate or triplicate[a] to the New Projects Unit for

[a] One copy for biologist review, one copy to the manager-advisor,

distribution to the biological review participants. Review comments are sent back to New Projects for compilation before submission to Engineering. Where disagreement among the biological reviewers arises, the consensus and hierarchical decision-making sequence described in the previous section is used. This pathway ensures consistency of comments back to Engineering. Further meetings are then scheduled through the New Projects Unit, as circumstances dictate.

Although the biological group finds both the site layout and flow schematic diagrams particularly useful in understanding further blueprints, only the former has been regularly provided by the Engineering Division. We strongly agree with Jeppson and Taylor (1981) that visual aids of this nature are far more useful in the initial stages than are complex drawings of the proposed facilities. Another item considered useful and often requested by New Projects, but rarely provided by Engineering, is a written list of assumptions used in developing the design under review. Part of the problem may have been that Engineering was unable to determine those assumptions of relevance to the biological group. Where required to obtain such listings, New Projects staff have undertaken initial reviews of the submitted plans, prepared lists of key questions, met with the project engineers, and added information notes to the plans sent out to biological review.

Step 8 - Costing of Facility Operation

In preparation of the Treasury Board Submission required for all projects over $500,000, ($1,000,000 as of August, 1983) facility operating costs are estimated. Two methods of estimation have been employed. When site and stock logistics are well known, the Head of the relevant Operations Unit may undertake a detailed program budget exercise. When logistics are less certain, the predictive formulae developed for the EOS exercise (see Table 10) have proved useful. Where both methods were used, the difference between the two independent estimates has not exceeded 20% and was normally within 10%.

The Engineering Division works up the estimated capital costs of the facility on the basis of the finalized conceptual design; the only responsibility that Enhancement Operations has in this area is to estimate and ensure inclusion of capital for the purchase of equipment for start-up.

Step 9 - Production Forecasts

The New Projects Unit has responsibility for the development of production forecasts, which also are required for the Treasury Board Submission. Calculations are done up to the point of full adult returns, using a 'VISICALC' program and the best available biostandards information. Sources for the latter include McDonald (MS 1979), the more recent update done by the Ad Hoc Biostandards

Table 10. Predictive formulae for estimating SEP facility operating costs (developed for EOS SEP Continuation planning exercise--see Lill et al, MS 1983).

TYPE OF OPERATION	COST FORMULA (82$)
(1) Manned Facilities	
a) Producing up to 3000 kg	$49,000 + $86/kg
b) Over 3000 kg	$275,000 + $5.50/kg
(2) Satellite Operation (one or two nearby systems)	$90,000 each (Additive to cost of Central Facility
(3) Semi-manned Incubation Box	$9,000 each
(4) Adult Transplant or Trap-and-Truck Operation	$51,000 each
(5) Juvenile Stocking or Colonization	$27,000 each
(6) Juvenile Transplant	
a) Requiring Onsite Box Incubation	$99,000 each (Box + Satellite Costs)
b) Offsite Incubation	$90,000 + $86/kg or $90,000 + $5.50/kg (dependent on size of Central Facility)

NOTE: Does not include capital equipment or maintenance costs.

Committee, and data from the feasibility studies. Any assumptions or criteria used in the absence of actual data are documented within the forecast table. Examples of completed 'hatchery return' and 'natural spawning' production forecasts are provided in Appendix 11 (when the hatchery's objectives include rehabilitation of naturally spawning stocks to historic levels, a secondary forecast is done which predicts the production from the natural spawning of hatchery-origin fish).

Steps 10 and 11 - Treasury Board Submission and Approval

The preparation of a Treasury Board (TB) Submission is required for any capital project exceeding $500,000 ($1,000,000 as of August, 1983). The Chief of SEP Engineering is responsible for completion of the Submission document. The document's format follows TB guidelines, as laid down in various internal policy manuals. The project is assigned to a TB Analyst who advises the Engineering Chief as to procedures and the level of detail required for the Submission (A.F. Lill, pers. comm.). At the request of the Engineering Chief, various of the SEP groups provide work-ups for inclusion as appendices to the Submission. Through the New Projects Unit, Enhancement Operations provides production returns and operations costs (see Steps 8 and 9); Engineering predicts capital costs on the basis of the conceptual design; and socioeconomic evaluations are provided by Program Development economists. The Engineering Chief drafts the text of the Submission, and the package is reviewed for accuracy by the various participants. The Submission is sent to Ottawa, signed by the Deputy Minister or Minister, and passed to the TB Analyst, who prepares a Briefing Note. The Briefing Note is confidential and is the document actually used by the TB in making the decision to fund the project (A.F. Lill, pers. comm.)

It is worth noting that, in the past, the TB Submission often preceded completion of biofeasibility studies, resulting in imprecise project requirements and costs. Often, Amendment Submissions would then have to be made if there were cost overruns. More recently, it has been the practice to make a Preliminary Submission for funds to undertake detailed design work, then to make a Final Submission when the design work is completed. This approach should aid in increasing the accuracy of the Submission's projections. Such accuracy is extremely important, as project performance is held accountable on the basis of the claims made in the Submission.

Step 12 - Detailed Design

Upon receiving TB Approval, SEP Engineering begins detailed design work. Although the major elements of design have been set by the conceptual design, there is a continuing need for biological input throughout this period. Biological advice during work-up of

drawings is provided to Engineering in one of three major ways. First, New Projects staff directly input if the criteria are straightforward. Second, where uncertainty exists as to requirements, New Projects staff will query the Operations staff as to their wishes. Third, where it has been possible to appoint a hatchery manager during construction, the manager directly provides much of the biological advice. As has been stated elsewhere, the New Projects Unit is committed to documentation and consistency of biological input to facility design. Thus, in the first two communications pathways, New Projects staff will issue memo reports for all items of consequence. Documentation of input by the manager has generally not been as thorough and some information gaps may exist. Although the initial manager may be aware of the "whys" through direct experience, succeeding managers may have to guess at the rationale that was used. Therefore, formal feed-back by the manager to the New Projects Unit is encouraged, so that all bioengineering design decisions can be included in the as-built review document (see Step 17).

Step 13 - Detailed Design Review

Depending on the size and complexity of the facility, Engineering may choose to break the design work into several contract packages. Prior to each package going out to tender, the drawings are passed by Engineering to the New Projects Unit for biological review (as per Steps 5 and 6). New Projects oversees the biological review sequence; drawings are stamped with a circulation list, and the deadline for completion of review is identified and followed up on. Where the drawings are particularly complex, it is helpful to have an orientation meeting with the project engineers prior to the formal biological review proceeding. As mentioned in Step 7, it is desirable to have Engineering provide visual aids and key assumption lists in order to assist in orientation. At first, the biological review was the last step prior to tendering (the date of which is advertised well in advance). Delays experienced in the prior stages of design accumulated and were directly subtracted from the time allowed for review. This led to inadequate biological review time and, in some cases, rather costly contract amendments or sub-optimal facilities. More recently, the Engineering group has improved this situation by providing preliminary drawings as they are draughted, rather than waiting for their final assembly into the tender package.

When the review rsults in requests for only minor changes, these are informally relayed by New Projects to Engineering; where changes are more substantial, New Projects prepares a memo request. If the review points up serious disagreement between the Engineering approach and biological needs, follow-up meetings may be required to resolve the problem. Prior distribution of the meeting agenda and subsequent distribution of minutes of the

meeting (highlighting decisions reached and action items) result in more effective communication. Where agreement cannot be reached at the project level, it will be referred to senior staff, up to the Executive Director's level if necessary, for decision.

Steps 14 to 16 - Design Completion, Final Review, and Project to Tender

Engineering revises the drawings subsequent to the detailed design review and puts them out to tender. The final tender drawings are double-checked by New Projects to ensure inclusion of all changes requested and agreed to, and are circulated to the other biological reviewers for their information.

PILOTS

Where biological feasibility studies point up marginal or uncertain conditions which would make the success of a production-scale facility questionable (water quality, for example), the New Projects Unit will recommend a pilot where possible. These pilots generally have short lifetimes and thus are constructed in a modular or mobile fashion, and they are sized to meet specific experimental needs. The term 'pilot' also has been used in the past for other types of small operations, such as: mini-hatcheries to obtain adequate numbers of juveniles for coded-wire tagging to estimate fishery contributions (such as Atnarko, Fulton and Kitimat chinook); the start-up year of a production-scale facility; minor facilities that deal with small numbers of fish such as Blaney, Inch and Birkenhead; or first-stage facilities operated to give staff logistical knowledge of the area and stocks. From the New Projects Unit's perspective, these are not pilots in that they do not act as guides through difficulties or dangers. The pilots undertaken by Enhancement Operations during Phase I of SEP are listed in Table 11.

The pilots are developed using a design/review process similar to that previously described for production-scale facilities. The New Projects Unit may request research expertise from the Pacific Biological Station to address specific problems. It is preferable to have the relevant Operations Unit heavily involved in operation of the pilot, as errors in fish culture are reduced, staff familiarity with the site and stocks is increased, and much of the logistical load is removed from New Projects. One weakness in this approach is the often severe delays experienced between termination of the pilot and reporting. This problem has yet to be resolved satisfactorily, as manpower allocations have not kept pace with increasing project loads.

AS-BUILT REVIEW DOCUMENT

In order to link design criteria and operational reality, the

Table 11. Pilots undertaken by SEP during Phase I (1976-84).

Pilot(s)	Years Operated	Equipment[a]	Purpose (Species)[b]
Atnarko	75-79	7.4M eggs in gravel incubators.	Test feasibility of gravel incubators at production scale + rebuild odd-year stock (PK).
Bowron (1 stock)	80-81	75K egg gravel box; Cap trough.	Develop cold-water culture techniques (CN).
'Central Interior Package'			Investigate rearing and imprinting success of hatchery outplants:
Clearwater	84-	650K eggs in vertical trays;	+ upstream and downstream outplants (CN/CO)
Shuswap (1 stock)	84-	110K eggs in vertical trays; Cap troughs.	+ upstream colonization above dam (CN)
Spius (3 stocks)	84-	325K eggs in vertical trays; Cap troughs; Al raceways.	+ solar heating and effluent control technology (CN/CO)
Stuart (1 stock)	80-81 83-	110K eggs in vert. trays; Cap troughs.	+ effects of marginally high Fe in groundwater supply (CN).
Chehalis (3 stocks)	80-81	123K eggs in vertical trays; Cap troughs.	Test effects of marginal pH and soft water (CO/RT/CN).
Eagle (4 stocks)	83-	1M eggs in vertical trays; Cap troughs; Al raceways.	Investigate rearing and imprinting success of hatchery outplants (CN/CO).
Indian (2 stocks)	79-81	250K CN eggs in vertical trays; Cap troughs; earthen channels (CN). Seapens (120K CO).	Test low-pH, soft groundwater (CN); examine possibility of establishing resident CO for year-round saltwater sportfishery.
Kalum (1-2 stocks)	80-83	200K eggs in gravel boxes, then vertical trays; Cap troughs.	Develop cold-water culture techniques (80-82); time and size of release (82-83) (CN).
Mathers	80-83	800K eggs in vertical trays and Pallant boxes; Aqua-Breeders' raceways.	Test effect of marginally high ammonia levels in groundwater supply.
Mussel (1-2 stocks)	84-	500K eggs in vertical trays; Cap troughs; swimming pools.	Test impact of sockeye run with IHN above hatchery water supply.
Penny (1 stock)	80-81	75K egg gravel box; Cap trough.	Develop cold-water culture techniques (CN).
Thornton (1 stock)	76-79	1M eggs in Atkins/free-styles; keeper channels; swimming pools.	Test Japanese chum culture techniques (CM).

[a] Cap = Capilano; Al = Aluminum

[b] Species Code CN = Chinook; CO = Coho; CM = Chum; PK = Pink; RT = Rainbow Trout.

New Projects Unit has one last major duty for each new production facility. At the conclusion of the start-up year, the New Projects Unit produces a report integrating all the biological design information with the as-built structures actually provided, and with the additional biological data generated in the first year of operation. The report is meant primarily as a reference document to ensure operator access to original design assumptions and strategy. In addition, capacity and timing calculations are reworked where new data or changes in existing structures make it necessary, data gaps are identified for staff action, and alternate strategies may be suggested where appropriate. This report is complementary to the operations manual produced for each facility by the Engineering Division. The biological review report is distributed to the facility and its manager, the operations support biologist and Head of the Operations Unit, the Biological Program Coordination Unit, the Chief of Enhancement Operations, and the engineers responsible for the project.

As noted for the operation of pilots, formal feedback of start-up data from the operators can be difficult to obtain, yet is essential to ensure relevancy of the final report.

DISCUSSION

PROBLEM AREAS

Communication

A point made throughout this report is that efficient communication on several levels is essential to optimal facility design . Without rapid and accurate feedback to the New Projects Unit from operations biologists, facility managers and fish culturists, outdated criteria or inappropriate containers will continue to be used for new facilities.

In general, complaints regarding inadequate lines of communication are widespread within SEP and DFO and are common in large organizations, whether government or private-sector. It appears that there is a critical size of organization beyond which information/communication systems must be developed and standardized (see Kelly, 1969). In addition to being large, both DFO and SEP are complex, having several geographic and specialist groups. As specialists, biologists and engineers have very basic differences in approach, which seems to stem largely from their professional training rather than from individual personalities. For instance, in dealing with biologists and engineers from the Washington Department of Fisheries, I have observed uncannily similar frictions and attitudes to those seen within SEP. These factors should be considered in any effort to improve communications.

Project Management and Authority

There are a number of ways in which the activities of an organization can be grouped (Barnes et al, 1970). Comments made here relate to the facility design process, which employs an informal version of the "Project Management" or "Task Force" approach.

The Project Management approach is most appropriate for the implementation of large and complex projects requiring inter-disciplinary collaboration (Quick, 1972). Of the three main project management structures (see Table 12), the SEP facility design process comes closest to the "Division Responsibility Project" type. This type of structure, by definition, reduces the project manager's responsibility and authority to a coordination role (see Figure 6). In fact, SEP does not appoint project managers; there is a sharing of leadership dependent on the aspect being dealt with at the time. Dupuis et al (MS 1980) considered it especially important that the project or project manager have a clearly-communicated authority from senior management where a variety of divisions are requested to provide personnel, information, or assistance to accomplish the project. SEP projects do not arise in a consistent manner from a management committee or senior management, but often are identified by units or divisions.

Of the various groups involved in the SEP facility bioengineering process, the senior engineers come closest to functioning as project managers. In terms of project management theory, Enhancement Operations presently carries a confusing blend of project manager, client, and staff responsibilities. In addition, without joint bioengineering planning and updating, critical paths can separate, resulting in either project delay or use of insufficient data in project design.

Finally, a project manager must be responsible for developing effective documentation, communication and updating procedures for both staff and clients, as these are an essential element of project management (Dupuis et al, 1980). Insufficient emphasis has been placed on this aspect of project management for the SEP projects that I have been involved in.

POTENTIAL SOLUTIONS

It is easy to say that communication must be improved; however, there is no standard approach effective in all situations. Kelly (1969) has defined the object of communication to be the reduction of uncertainty. Using that as the operational definition, what could be done to improve the SEP bioengineering process?

(1) Where there is commitment to a significant program for

Table 12. The three major types of project management structure (from Dupuis et al, MS 1980)

1. DURATION PROJECTS
   - the Project Manager and project staff are assigned to the project for the duration of the project's existence
   - assignment is usually on a full time basis
   - certain staff may be only assigned for parts of the project
   - the project manager and staff will not have other tasks assigned to them which could disrupt the planning and scheduling of work on the project

2. MATRIX-BANK PROJECTS
   - the Project Manager is usually full time
   - project staff is matrixed in on a part-time basis to accomplish a certain task
   - the Project Manager coordinates

3. DIVISION RESPONSIBILITY PROJECT
   - functional units or divisions of organization(s) are assigned certain tasks
   - their work is coordinated by a project manager
   - there may be a small project staff working on a part or full-time basis as well

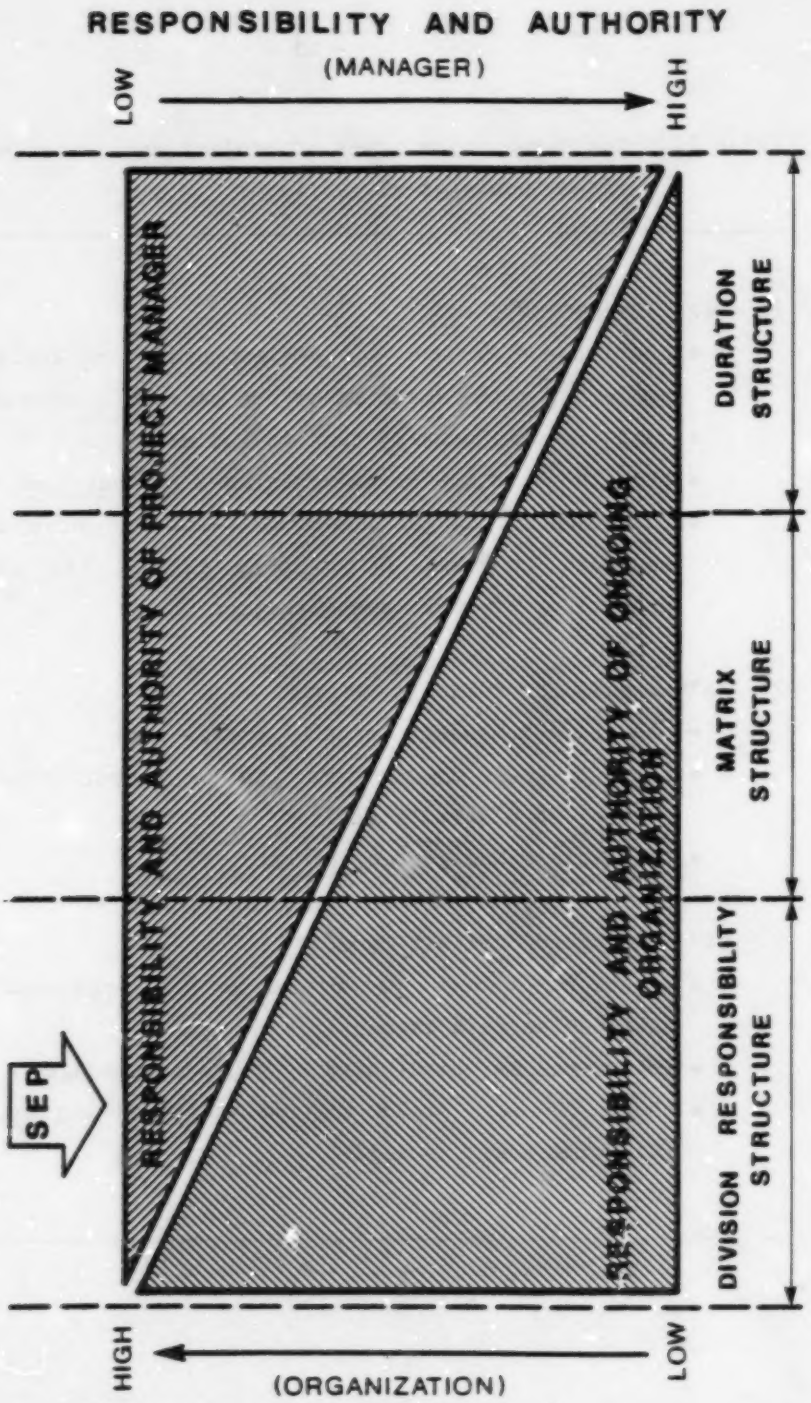

Figure 6 The levels of responsibility and authority of the project manager and the ongoing organization in relation to the types of project management structure (adapted from Dupuis et al., MS 1980).

development of enhancement facilities, appointment of a project manager and clear definition of his authority by senior management could reduce conflict, confusion and duplication of effort. It is worth noting that total elimination of conflict should not be expected, as it is considered inevitable if the project is to progress in a healthy manner (Quick, 1972).

(2) The keystone of the task force management approach is consensus (Quick, 1972). The project manager should not make critical decisions independently. Such an authoritarian approach will result in a lack of staff commitment to the project. Rather, the project manager should have excellent mediation skills and must be able to motivate the most appropriate staff to develop timely and thorough answers to key questions.

(3) The Task Force membership should incorporate both regional and specialist expertise. On a personal level, all members have to strive consciously towards mutual problem-solving, rather than working in a win-lose mode. Strengthening intergroup and interprofessional communications can aid in fostering mutual respect through an awareness of the other's constraints and problems. For example, it is extremely helpful to the biological staff if Engineering staff formally document their assumptions and approaches beyond the initial joint conceptual design of a facility.

(4) Both inside and outside of the task force, formal documentation and feedback channels should be followed, as research into group dynamics indicates that structured communication is usually more effective than unstructured (Kelly, 1969). Examples of productive pathways are: dissemination of minutes of meetings; distribution of group program and activity plans (eg, the Fieldwork Bulletin); and regular update reports (eg, the biweekly Enhancement Operations Status Reports).

To better deal with resource limitations, the New Projects Unit has strived towards further streamlining of its activities. At present, a computer-assisted design program is nearing completion and will be documented in a forthcoming report. Coordination of bioreconnaissance users via Fieldwork Bulletins or other means may result in more effective use of funds through joint studies. Greater use will be made of special-interest groups, such as the Salmonid Culture Managers' Advisory Committee, to address criteria gaps.

ACHIEVEMENTS TO DATE

It is worth making the point that, although the present bio-

engineering process is not perfect, it has allowed us to implement considerable production capacity successfully. Since 1976, the total egg capacity at Enhancement Operations facilities has been increased by 34%, or an additional 222 million eggs (Table 15). Up to 1982, better than half of this new capacity had been utilized. Of the facilities operating in 1982, those that started in 1980 or earlier were at 58% of capacity while those that started in 1981 or later (excluding Kitimat) were already at 49% of capacity. Large and complex facilities such as Chehalis and Kitimat are going into the operational mode very smoothly. There are many reasons for the smoother and more rapid approach to capacity at recent facilities, but I feel a large measure of the credit is due to improvements in the bioengineering process.

Table 13. Enhancement Operations facilities: status and final capacities as of June, 1983

PROGRAM AREA	PROJECT	YEAR OF FIRST EGGS	CAPACITY IN M EGGS	1982 TAKE IN M EGGS
PRE-SEP	BEAR	1975	5.00	0.00[b]
	BIG QUALICUM	1967	145.46	209.64[d]
	CAPILANO	1971	3.74	2.75
	FULTON	1965	360.00	720.00[d]
	JONES	1954	2.50	0.00[c]
	PINKUT	1966	117.00	280.00[d]
	QUINSAM	1974	10.45	7.90
	ROBERTSON	1972	11.00	12.63
PRE-SEP TOTAL			655.15	1,232.92
SEP	BIRKENHEAD	1979	0.15	0.16
	CHEHALIS	1982	18.10	12.95
	CHILLIWACK	1980	7.40	7.57
	INCH'S	1981	8.25	7.15
	KALUM[a]	1981	0.20	0.22
	KITIMAT	1983	15.13	0.35[a]
	LITTLE QUALICUM	1979	75.00	41.29
	MATHERS[a]	1980	1.10	0.30
	NITINAT	1980	29.50	11.86
	PALLANT	1978	9.80	5.01
	PENNY[a]	1980	0.20	0.20
	PUNTLEDGE	1979	22.80	15.12
	QUESNEL	1981	3.90	1.64
	SNOOTLI	1978	9.47	4.46
	STUART[a]	1980	0.10	0.07
	TENDERFOOT	1982	0.45	0.47
	TLUPANA	1978	25.00	21.83
	TSOLUM	1980	4.00	0.00[c]
SEP TOTALS				
START UP TO 1980			184.52	107.87
START AFTER 1980			46.03	15.63
OVERALL			230.55	123.50

[a] Pilot operation
[b] Odd-year operation only
[c] Off cycle year
[d] Includes river production (flow control on Big Qualicum and Fulton; air lift above falls at Pinkut)

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